

Integration of 300 mm Fab layouts and Material Handling Automation

Devadas Pillai
Intel Corporation
Chandler, AZ USA

Tim Quinn
Intel Corporation
Chandler, AZ USA

Ken Kryder
Intel Corporation
Chandler, AZ USA

Dan Charlson
Intel Corporation
Chandler, AZ USA

Abstract – We present key approaches and methodologies from Intel's 300mm factory integration efforts. The topics discussed in this paper are aimed at cross-functional optimization of fab layouts, automated material handling systems (AMHS) and operations. We discuss the key benefits of up front understanding of the interactions and investigate specific attributes in layouts and AMHS configurations where the integrated design/analysis is addressing cost-benefits and flexibility trade-off's needed in the high volume 300mm factories.

INTRODUCTION

Historically in 200mm high volume manufacturing (HVM), integrating an AMHS into fab layouts is often an afterthought. Great pains are first expended to insure layouts are conducive to efficient people operations, manual work in process (WIP) flows, based on a tight (densely packed) production equipment installation methodology. After this is done, the AMHS is required to adapt to the remaining space and constraints of the layout and building. Such a system is often not optimal and very susceptible to layout and operational methodology changes[3]. Intel had to re-look at traditional factory layout approaches for 300mm due to a variety of reasons. The 25-wafer front opening unified pod (FOUP) is 18 lb. in weight and 3 ft³ in volume, making it incompatible for frequent manual carrying and lifting. Use of personnel guided vehicles (PGV) offer temporary relief, but studies indicate the size, number of carts, and frequency of WIP transport in HVM makes it a very difficult for efficient operation. Combined with ergonomic constraints, bay traffic congestion, and need for PGV parking space, we believe a 100% PGV approach will likely not be practical for 300mm HVM. It was imperative that cost effective material handling solutions be developed that can meet the operational demands and demonstrate, extendibility, and flexibility traits required during the life cycle of a 300mm fab.

To ensure solutions meet these overall goals, a cross-functional group consisting of domain experts from construction, building designs, automation, layout, production equipment, and factory operations have been meeting regularly to drive an integrated decision making methodology in the realms of production and AMHS equipment configuration, layouts and operations. The team first realized it is the factory layout that collectively brings these diverse requirements together. Perceiving this need, Intel has been very proactive in the international 300mm consortia driving for equipment, facilities, and AMHS standards[2] to reduce cost and ease of implementation. We

believe there now exists a comprehensive set of physical interface and communications standards[4] agreed to globally[1] by device makers, which forms the core of factory integration solutions linking layouts, AMHS and operations.

Focus of Work

We list below some of the many areas addressed by this cross-functional effort:

- Bay-widths and chase-widths dimensions to provide the needed equipment move-in/move out flexibility and at the same time provide maximum output per unit factory area.
- Identification of optimal Stocker placement locations and intrabay Overhead Hoist Transport (OHT) routing configuration that provides flexibility for frequent layout changes and bay pitch changes .
- Development of intrabay throughput capacity models that estimates equipment throughput and batching together with interbay/intrabay throughput limits and defines a combination of process and metrology equipment quantities for each bay or OHT loop.
- Development of layout best known methods based on algorithms for linking multiple bays by one Intrabay OHT loop and calculating cost effective quantities of Stockers and OHVs (overhead hoist vehicles).
- Placement of in-line metrology equipment in the layout and its impact to operational efficiency if metrology equipment is centralized or distributed and corresponding OHT delivery (transport) times.

We summarize steps taken in the first three items listed above, discuss integration efforts between layouts, operations and AMHS domains, and discuss key findings, conclusions and next steps.

BAY WIDTH and CHASE MOVE-IN WIDTH

The objective of evaluations in this key area was to understand the optimal bay widths and chase equipment move-in clearances for high volume manufacturing which comprehended (1) need for maximum output per square foot of cleanroom, (2) providing operational efficiency for PGV traffic and (3) clearances for equipment move-in/move-out during process changes and retrofits.

The first step was to get agreement on a uniform bay width across the factory and an overall agreement on equipment move-in/move-out requirements during equipment install

and (future) de-install. Since OHT loops were in the bays and suspended from bay ceiling, studies showed that equipment moves through the bay was impractical because the OHT loop operation must be halted during the period of equipment relocation. This would directly impact the output of other equipment serviced by the same OHT loop. Studies were performed to ensure equipment moves could be accomplished through the chase of each functional area. The recommendation was all equipment moves would occur through chases and not through the bays. (See Fig. 1).

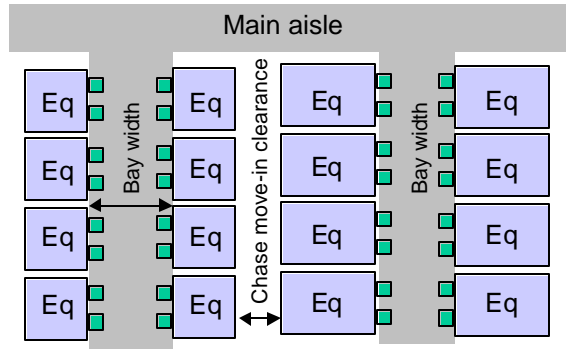
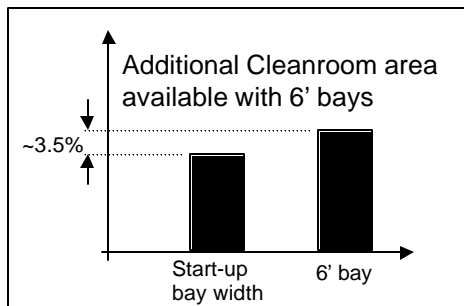


Fig. 1 Bay width and chase clearance definitions

Bay widths ranging between 6 feet to 10 feet wide were evaluated. Key factors driving bay width decisions were (1) providing a solution that would allow use of PGVs as backup within each bay during OHT failures and still allowing U.S code mandated people exiting requirements and (2) a requirement to not allow simultaneous PGV docking on opposing equipment in a bay. Evaluations indicated simultaneous PGV docking would require 9.5 feet wide bays. If OHT reliability was very high so as to eliminate need for PGVs, then bay widths across the factory may be reduced to 6 feet. Studies indicated that bay widths could be reduced to as low as 6 feet in Litho bays, where there were no walls. The 6 feet wide bays resulted in 3.5% increase in available cleanroom area as shown in Graph 1.



Graph 1. Impact of 6' wide bays on cleanroom area

The studies also revealed the need to increase bay length to accommodate larger 300mm equipment and to increase number of equipment installed in the cleanroom. Recommendations were made to move out the fab perimeter walls to the exterior of the perimeter columns. This key decision resulted in two big advantages. It added an additional 1.5% to the cleanroom area and also provided

the needed OHT turning radius and track over-run at the ends of the bays so as to increase OHT accessibility to the last production equipment (loadports) within each bay.

STOCKER PLACEMENT FOR LAYOUT FLEXIBILITY

In 200mm, with floor-running rail guided vehicles (RGV) for intrabay applications, Stocker placement decisions were generally tied to the location of the fab bays they serviced. This limitation, shown in Fig. 2 is called bay-pitch dependent Stocker locations. This causes significant layout issues during layout changes whenever a new piece of equipment was larger in the depth dimension than its predecessor.

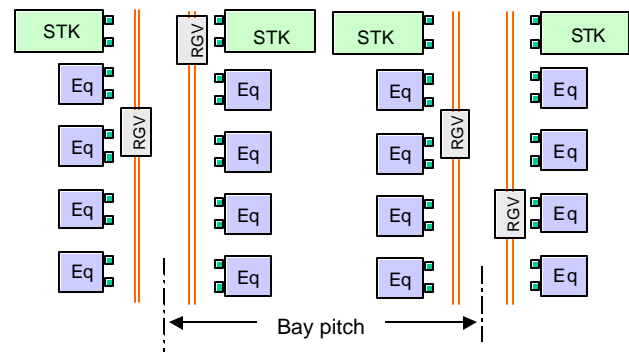


Fig. 2 Bay pitch dependent Stocker locations (common scenario in 200mm with RGV)

In 300mm, it was imperative a design approach be developed that eliminates the need to relocate any Stocker whenever a major layout change occurred causing bay pitch and bay wall changes. This design activity was greatly aided with the advent of the OHT technology for 300mm intrabay. By routing OHT tracks in the ceiling, it was not necessary to align the Stocker front end to the front end (equipment boundary) of the production equipment. This enabling feature has allowed layout designers to explore layout options for 300mm that de-links the Stocker location and permits it to be independent of the bay pitch, as shown in Fig. 3. As equipment mix changes over time, the bays have the flexibility to move either to the left or right without the need for Stocker relocation at the any time.

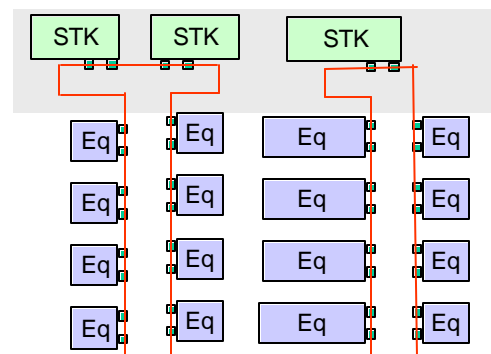


Fig. 3. Bay pitch independent Stocker locations

The intrabay OHT also permitted more than two Stockers to be linked to one intrabay loop, thereby increasing the storage capability of the system. The design was also aided by the decision to place all Stockers in the central core of the cleanroom, independent of the processing bays. This also allowed AMHS system design to proceed at a pace independent of the date for determining the final production equipment placement in the layout. Furthermore, it also helped to minimize the number of different configurations of Stockers in the factory.

A third layout option evaluated was the concept of multi-bay linking by the same OHT loop as shown in Fig 4. As it can be seen, this concept demonstrates all the advantages of bay-pitch independency plus providing the capability of consolidating lots into a few number of Stockers compared to Fig 3. The material handling routing logic enables the Stacker robots and the Stacker storage levels to be automatically equalized (load-leveling) resulting in balanced Stacker robot utilization and more consistent delivery times and transportation times of the system.

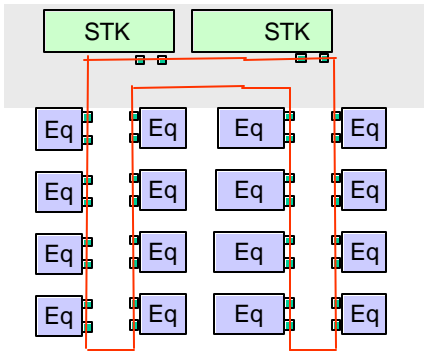


Fig. 4 Bay pitch independent and multi-bay linking

Designs shown in Figs. 3 and 4 also demonstrated the capability for the need for fewer Stockers compared to Fig. 2. At the same time, identical AMHS performance indicators were demonstrated in the simulations. Configuration comparisons are shown in Table 1 below, when aggregated across the whole factory.

Layout Option	No. of Stockers	No. of OHVs
Fig. 2	X	Y
Fig. 3	0.7X	Y
Fig. 4	0.6X	1.05Y

Table 1. AMHS configuration impacts of layout options

Since Stacker quantities drive the overall cost of the AMHS, any reduction in Stacker quantities directly impacts the overall cost of the AMHS in a big way. As it can be seen from Table 1, the cost reduction is significant when aggregated across the whole factory and providing layout change flexibility.

The team performed a study of the number of bays that are candidates for multi-bay linking versus the number of bays whose throughputs are so high that they required individual OHT loops. Chart 1 indicates the typical split between linked and un-linked bays in a typical high volume fab. As it can be inferred, multi-bay linking provides significant material handling system cost reduction.

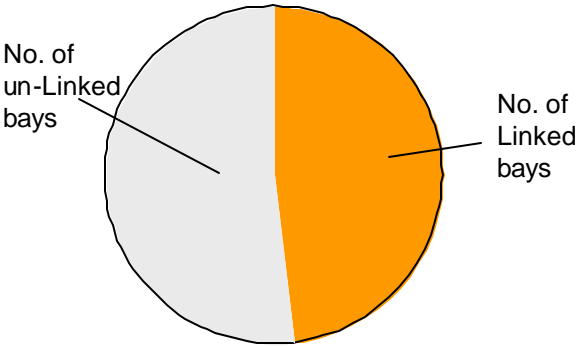


Chart 1. Linked versus Un-linked bay configurations

Table 2 below shows the advantages and disadvantages of Linked OHT loops:

Advantages of Linking	Disadvantages of Linking
<p>~40% reduction in Stacker quantities across the factory.</p> <p>Better system reliability, as there were fewer components.</p> <p>Provides significant AMHS cost savings.</p> <p>Reduces some of the moves on the Interbay transport loops.</p> <p>Reduces the number of OHT controllers in the fab.</p> <p>Provides better load-leveling of Stacker robot and Stacker storage and therefore minimizing transport delivery time of most bays</p>	<p>Increases risk to the factory output if the OHT reliability is below specifications. Linking puts more production equipment on one loop.</p> <p>There could be some increase in the number of intrabay vehicles needed.</p> <p>Linking may increase the delivery time of some bays.</p>

Table 2. Advantages and disadvantages of multi-bay linking using OHT.

INTRABAY THROUGHPUT CAPACITY ESTIMATOR

To estimate the throughput capacity of a bay and the required transportation needs based on the mix of production equipment in that bay or combination of adjacent bays, the team developed a software throughput estimator called the Bay Layout Tool (or BLT). The BLT helps factory manufacturing engineers, with very little AMHS experience, to determine the maximum number of production equipment that can be serviced by one intrabay OHT Loop.

The BLT also enables a user to understand the throughput sensitivity of this system as additional vehicles are added and the OHT loop is increased in length. Two metrics were used to determine the system performance of the OHT system. One was sustained "peak throughput capability" of the system; i.e., the maximum sustainable number of FOUPs transported per hour in the loop without reduction to bay output. The other metric was system "delivery time; i.e., the time taken to move a FOUP from Stocker (shelf) to a equipment load-port prior to processing and vice versa back into the Stocker shelf after processing is complete.

The data revealed the biggest drivers of the system throughout and intrabay delivery time were (1) the cycle time needed for an OHT vehicle to load or unload a FOUP at a load port and (2) the Stocker cycle time and (3) the OHT vehicle travel velocity. System performance characterization around these three parameters was a central ingredient of the BLT.

The BLT permits a user to place any combination of production equipment in a particular bay or a group of bays that was to be serviced by an OHT loop. It would comprehend production +equipment run-rates (wafers processed per hour) of each equipment, its processing batch size in lots, and would require a user to input the average utilization of each equipment selected to be serviced by the OHT loop. Once this was done, the BLT would compare the required total throughput of all production equipment connected to the OHT loop to the throughput ability of the OHT system, and determine whether the loop could support the throughput needed or not. This up-front planning model permitted a layout engineer to perform several combination of process and metrology equipment layout options and then develop a "Best Known Method" or BKM that can be re-used over and over again, saving significant design and analysis time.

NEXT STEPS

The material handling technologies addressed in this paper are applicable for the first two generations of 300mm process technologies. Per the Factory Integration chapter of the International Technology Roadmap of Semiconductors [5], material handling systems would see major changes in

the future, culminating in the availability of "direct transportation" systems. Using direct transport systems, differentiation between interbay and intrabay systems would be eliminated and lots would be directly transported from equipment to equipment (loadports) and Stockers. This vision of the factory would have a few large capacity Stockers, located strategically in the factory (not consuming cleanroom space) plus widespread use of fixed loadport buffering on all production equipment. Exceptions to loadport buffering would apply to diffusion and wet processing equipment, which would have internal buffering. In a factory scenario with direct transportation capability, many of the design and layout principles discussed here will evolve and be modified. It is imperative the direct transportation system be completely integrated into fab layouts, loadport buffering and manufacturing operations right from the start to make it successful.

ACKNOWLEDGEMENT

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